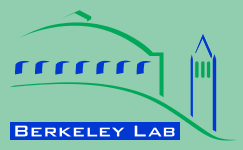

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China's Industrial Carbon Dioxide Emissions in Manufacturing Subsectors and in Selected Provinces

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Contents

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Abstract

In 2009, China announced a goal to reduce its carbon dioxide intensity (CO_2/unit of gross domestic product) by 40-45% by 2020 from the 2005 level. In 2011, China established a goal of reducing its CO_2 intensity by 17% during the 12th Five-Year Plan period (2011-2015). Five provinces and eight cities have been selected to pilot low-carbon activities and are required to establish local-level emissions inventories.

The industrial sector dominates the country's energy-related CO_2 emissions, using two thirds of the total energy consumption. A better understanding of China's industrial energy use and CO_2 emissions at the sub-sectoral and provincial levels can assist researchers and decision-makers in identifying the largest areas of energy-saving and emission-reduction potential. However, previous studies have largely focused on China's energy use and CO_2 emissions at an aggregated level. Based on publicly-available information, this paper estimates industrial energy-related CO_2 emissions for each manufacturing sub-sector at the national level and in twelve provinces, including: Chongqing, Guangdong, Hebei, Henan, Jiangsu, Liaoning, Shaanxi, Shandong, Shanghai, Shanxi, Sichuan, and Xinjiang.

This paper first explains data availability issues and discusses the methodology as well as conversion factors used for the CO_2 emissions calculations. This paper then presents the results of the calculation of the carbon intensity of fuel and electricity for each manufacturing subsector and identifies the largest CO_2-emitting sub-sectors in the selected provinces. In addition, three provinces are highlighted, illustrating that economic and energy structure play an important role in the industrial CO_2 emissions within provinces. Finally, this paper discusses how to further improve carbon inventories at the sub-sectoral level and summarizes the findings of this study in light of China's current domestic carbon inventory efforts.

Introduction

In 2009, China announced a goal to reduce its carbon dioxide intensity (CO_2/unit of gross domestic product) by 40 to 45% by 2020 below the 2005 level. In 2011, China's announced a 2015 carbon intensity reduction target of 17% for the 12th Five-Year Plan period (2011-2015). In March 2011, the National Development and Reform Commission (NDRC) of China selected five provinces (Guangdong, Liaoning, Hubei, Shaanxi, and Yunnan) as well as eight cities (Tianjin, Chongqing, Shenzhen, Xiamen, Hangzhou, Nanchang, Guiyang, and Baoding) to pilot low-carbon activities. The piloted low carbon development zones were tasked with developing low-carbon development plans, establishing supporting policies for a low-carbon economy, and establishing greenhouse gas data collection and management systems.

In China, the industrial sector consumed approximately 70% of total energy use and emitted 72% of the energy-related CO_2 emissions in 2010, while in the U.S. and most developed countries the share of industrial energy consumption is considerably lower. Figure 1 below shows China's historical CO_2 emissions by sector, in comparison with U.S. CO_2 emission in 2010.

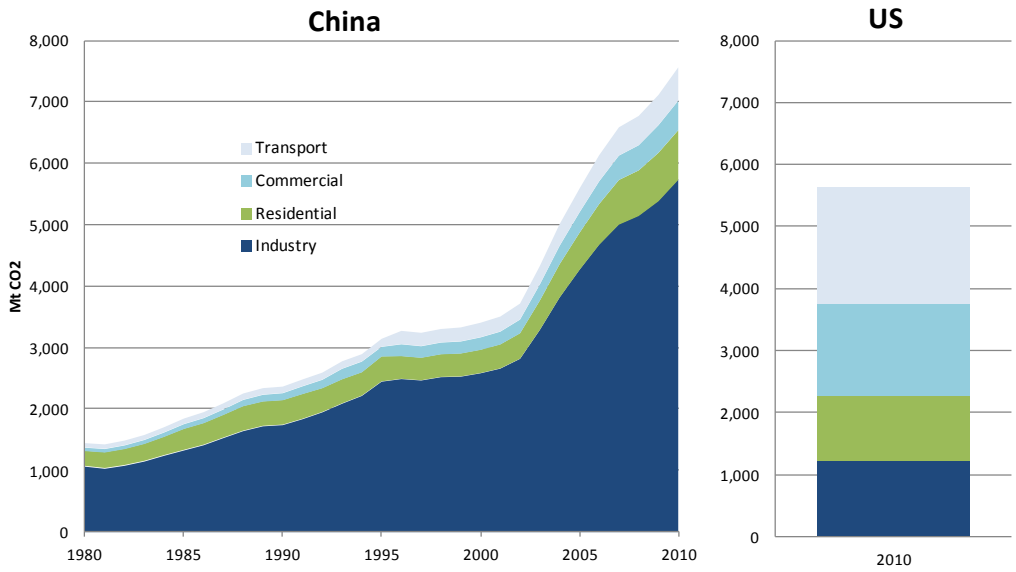

Figure 1. China's Energy-Related Carbon Dioxide Emissions (1980-2010)

Note: "Industry" on the chart includes construction and agriculture. "Industry" used in the text does not include construction or agriculture.

Sources: NBS, 2011; EIA, 2011.

China's industry also heavily relies on the use of coal. In 2008, less than 50% of the country's coal consumption was used in the power sector; the remaining 50% was consumed by industry directly (NBS, 2009). Industry is the key sector focus on in order to have an impact on China's energy and emission trajectories.

The industrial sector includes a variety of manufacturing subsectors, some of which are quite energy-intensive. To understand how energy is consumed in industry and which sectors have the largest CO_2 emissions, it is necessary to analyze the industrial sector at the sub-sectoral level.

Provinces in China differ a lot as well. Although many provinces are industry-focused, there are significant variations among their manufacturing sectors. For example, one province may have a large iron and steel industry, while another province may be a large exporter of telecommunication equipment. Understanding the industrial energy use and emissions at the provincial level can help identifying the largest potentials for increasing energy efficiency and mitigation emissions.

In this paper, energy use and CO_2 emissions of manufacturing subsectors for the selected provinces, including Chongqing, Guangdong, Hebei, Henan, Jiangsu, Liaoning, Shaanxi, Shandong, Shanghai, Shanxi, Sichuan, and Xinjiang, are calculated and analyzed. The purposes of this study are providing a transparent calculation and identifying the largest energy-consuming and CO_2-emitting industrial subsectors in the selected provinces.

Data Availability

The two key resources for national energy consumption data in China are the *China Statistical Yearbook* and the *China Energy Statistical Yearbook*, both of which are published annually by the National Bureau of Statistics (NBS) of China. The *China Statistical Yearbook* includes data and information on all sectors and areas in the economy, while the *China Energy Statistical Yearbook* provides more detailed information on energy use in all relevant sectors and industries. Provincial energy data are drawn from the provincial statistical yearbooks (SYB) published by each province. All the selected provinces published statistical yearbooks annually, and some of them are available on-line. For instance, the recent Jiangsu Statistical Yearbooks (2009 and 2010) can be accessed online (Jiangsu Statistics Bureau, 2009 and 2010).

However, although statistical yearbooks for provinces are available, not all the provinces provide energy data at the manufacturing sub-sectoral level. Six of the twelve selected provinces —Henan, Chongqing, Xinjiang, Shaanxi, Liaoning and Shanxi - have energy use by fuel for each industrial subsector in their statistical yearbooks. Three provinces –Shandong, Hebei, and Guangdong -- only have aggregated total energy use by industrial subsector. The other three provinces –Jiangsu, Sichuan, and Shanghai-- do not provide any energy use data by industrial subsector in their statistical yearbooks.

Table 1 summarizes the data sources and data availability for calculating CO_2 emissions in the manufacturing sector for China and each of the selected provinces. Without knowing the energy use of industrial subsectors, it is not possible to calculate CO_2 emissions. As no energy data are available from Jiangsu, Shanghai, and Sichuan, this study only calculates the emissions of the other nine provinces.

Table 1. Data Sources and Data Availability

National / Province	Data Source	Data Availability		Year of Data
		Total Energy Use	Energy Use by Fuel	
China	China Energy SYB 2009	Yes	Yes	2008
Chongqing	Chongqing SYB 2009	No	Yes	
Guangdong	Guangdong SYB 2009	Yes (ST)	No	
Hebei	Hebei SYB 2009	Yes (ST)	No	
Henan	Henan SYB 2009	Yes (ST)	Yes	
Jiangsu	Jiangsu SYB 2009	No	No	
Liaoning	Liaoning SYB 2009	No	Yes	
Shaanxi	Shaanxi SYB 2009	Yes (ST)	Yes	
Shandong	Shandong SYB 2009	Yes (ST)	No	
Shanghai	Shanghai SYB 2009	No	No	
Shanxi	Shanxi SYB 2009	Yes (ST)	Yes	
Sichuan	Sichuan SYB 2009	No	No	
Xinjiang	Xinjiang SYB 2008	Yes (ST)	Yes	2007

ST: data provided only in standard coal equivalents.

The selected provinces are mostly concentrated in the north and central China, with one province (Xinjiang) in the northwest, and another (Guangdong) in southern China. Figure 2 shows the locations of the selected provinces.

Figure 2. Geographic Locations of Selected Provinces

Note: Blue = selected provinces with data; dark green = selected provinces with no data available; light color= provinces that are not included in this study.

Scope of Industrial Subsectors

The National Bureau of Statistics (NBS) in China has established standards for categorizing industrial subsectors (NBS, n.d.). For example, Cement Manufacturing (NBS 3011) is under the category of Cement, Limestone and Gypsum Manufacturing (NBS 301), which is under the category of Manufacture of Non-metallic Mineral Products (NBS 30). The energy consumption of each subsector is reported based on this type of categorization. The energy use data reported in the *Energy Statistical Yearbook* and provincial statistical yearbooks are only for energy consumption at the two-digit level of industrial subsector, e.g., Manufacture of Non-metallic Mineral Products. Based on the NBS categorization, the Industry Sector includes: Mining and Quarrying, Manufacturing, and Electric Power, Gas and Water Production and Supply. For the purpose of this study, the calculation of CO_2 emission is only undertaken for the Manufacturing sector.

Methodology

For provinces that provide detailed energy use by fuel for each manufacturing subsector (Chongqing, Henan, Liaoning, Shaanxi, Shanxi and Xinjiang), subsectoral CO_2 emissions were calculated based on the following equation:

Subsectoral CO_2 Emissions = Physical Amount of Fuel Use × Low Heating Value of Corresponding Fuel × CO_2 Emission Factor of Corresponding Fuel

For provinces that only provide aggregated energy use for each industrial subsector (Hebei, Guangdong and Shandong), CO_2 emissions were calculated based on national average CO_2 emissions per unit of energy used in that subsector, as:

Subsectoral CO_2 Emissions= Total Energy Use by Industrial Subsector × National Average CO_2 Emissions per Unit of Energy Used of Corresponding Industrial Subsector

This calculation is solely based on emissions from fuel combustion and does not include process-related emissions.

Conversion Factors

This study uses the low heating values published by NBS for different types of fuel. NBS published 2008 national energy consumption by industrial subsector by fuel in standard coal equivalents and physical units. Based on the reported values, 1 kilogram of coal equivalent (kgce) equals 29.27 megajoules (MJ).

NBS annually publishes low heating values for fuels, such as crude oil and raw coal, and these values normally do not change much over the years. However, for some fuels, such as coke oven gas and other gas, NBS provides a range of low heating values. To determine the exact low heating values, this study calculated the conversion factor by dividing the standard coal equivalent value by the physical unit value, based on the reported values in the 2009 *China Energy Statistical Yearbook*. Table 2 lists the low heating values used in this study.

Table 2. Low Heating Values by Fuel

Fuel Type	Low Heating Values	Unit
Raw Coal	20,908	TJ/Mt
Cleaned Coal	26,344	TJ/Mt
Washed Coal	15,373	TJ/Mt
Coke	28,435	TJ/Mt
Coke Oven Gas	17,981	TJ/billion cubic meters
Other Gas	8,418	TJ/billion cubic meters
Other Coking Products	33,778	TJ/Mt
Crude Oil	41,816	TJ/Mt
Gasoline	43,070	TJ/Mt
Kerosene	43,070	TJ/Mt
Diesel	42,652	TJ/Mt
Fuel Oil	41,816	TJ/Mt
LPG	50,179	TJ/Mt
Refinery Gas	46,055	TJ/Mt
Other Petroleum Products	38,368	TJ/Mt
Natural Gas	38,931	TJ/billion cubic meters

Source: NBS, 2009.

This study adopted the carbon coefficients reported in the *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC, 1997a and IPCC, 1997b), as shown in

Table 3, and assumed 100% of carbon release from combustion.

Table 3. Carbon Coefficients by Fuel and CO_2 Emission Factors by Fuel

Fuel Type	Carbon Coefficient (t C/TJ)	CO_2 Coefficient (t CO_2/TJ)
Coal	25.8	95
Coke	29.5	108
Coke Oven Gas	13.0	48
Other Gas	13.0	48
Other Coking Products	21.6	79
Crude Oil	20.0	73
Gasoline	18.9	69
Kerosene	19.6	72
Diesel	20.2	74
Fuel Oil	21.1	77
LPG	17.2	63
Refinery Gas	18.2	67
Other Petroleum Products	21.6	79
Natural Gas	15.3	56

Source: IPCC, 1997a and IPCC, 1997b.

This study used the reported carbon coefficients of electricity consumption for provinces. NDRC published the carbon emission factors for thermal electricity by grid (NDRC, 2009) in 2009, as shown in Table 4 below. At the national level, carbon emission factors for electricity consumption are calculated based on the energy inputs of electricity generation of 2008. Thus, this calculated carbon coefficients for electricity at the national level only takes into account the emissions from electricity generation. Emissions from transmission and distribution (T&D) losses are included by using the reported average T&D losses.

Table 4. Carbon Emission Factors for Power Grids in China (2009)

Grid Name	OM (tCO_2/MWh)	BM (tCO_2/MWh)	CM (tCO_2/MWh)	Coverage of Provinces
North Grid	1.0069	0.7802	0.8936	Beijing, Tianjin, Hebei Province, Shanxi Province, Shandong Province, Inner Mongolia
Northeast Grid	1.1293	0.7242	0.9268	Liaoning Province, Jilin Province, Heilongjiang Province
East Grid	0.8825	0.6826	0.7826	Shanghai, Jiangsu Province, Zhejiang Province, Anhui Province, Fujian Province
Central Grid	1.1255	0.5802	0.8529	Henan Province, Hubei Province, Hunan Province, Jiangxi Province, Sichuan Province, Chongqing
Northwest	1.0246	0.6433	0.8340	Shaanxi Province, Gansu Province, Qinghai

Grid				Province, Ningxia, Xinjiang
Southern Grid	0.9987	0.5772	0.7880	Guangdong Province, Guangxi Province, Yunnan Province, Guizhou Province
Hainan Grid	0.8154	0.7297	0.7726	Hainan Province

Note: OM=Operating Margin, BM=Build Margin, CM=Combined Margin. CM is calculated as 50% OM and 50% BM. OM is the weighted average of operating margin emission factors from 2004-2006; BM is the build margin emission factors by the end of 2006.

Source: NDRC, 2009.

The heat content per kilowatt hour (kWh) of electricity is 0.1229 kgce/kWh, or 3596 KJ/kWh, which is used to convert electricity to final energy consumption in this study. For coal-fired power plants (with capacity no less than 6MW), the average coal consumption (including self-use electricity) in 2008 was 345 gce/kWh (SERC, 2010). The average T&D losses in 2008 were 6.64% (SERC, 2009). Thus, the average coal consumption per unit of electricity, including T&D losses, was 0.368 kgce/kWh. The conversion factor from final to primary electricity is 2.99.

Some provinces also provided data for heating energy use in industrial subsectors. To calculate CO_2 emissions from heating supply, the carbon coefficient of heat needs to be calculated. Based on the 2009 *China Energy Statistical Yearbook*, which provides energy use by fuel for heating supply, this study calculates CO_2 emissions per tera-joule (TJ) from heating supply in provinces, based on the low heating values and carbon coefficients of fuels as described above.

Results

Subsectoral CO2 Emissions at the National Level

In 2008, the manufacturing sector in China emitted 4,169 $MtCO_2$, without including the CO_2 emissions from electricity T&D losses. If CO_2 emissions from T&D losses are included, the total CO_2 emissions of the Chinese manufacturing sector in 2008 were 4,266 $MtCO_2$.

In terms of absolute CO_2 emissions, the subsector of smelting and processing ferrous metals has the highest emissions, about 1,350 $MtCO_2$ (without including emissions from T&D losses) or 1,370 $MtCO_2$ (including T&D losses). Manufacturing chemical raw materials and products, as well as manufacturing of non-metallic products are the second and third largest subsectors, respectively, each emitting more than 650 $MtCO_2$. The subsector of smelting and pressing of ferrous metals contributed the largest share, representing 32% of the total manufacturing CO_2 emissions. Manufacturing of raw chemical materials and chemical products, and the manufacturing of non-metallic mineral products each accounted for 16% of the total. The percentages vary little when adding emissions from T&D losses. Figure 3 shows the breakdown of CO_2 emissions (including CO_2 emissions from T&D losses) by the manufacturing subsector in China in 2008.

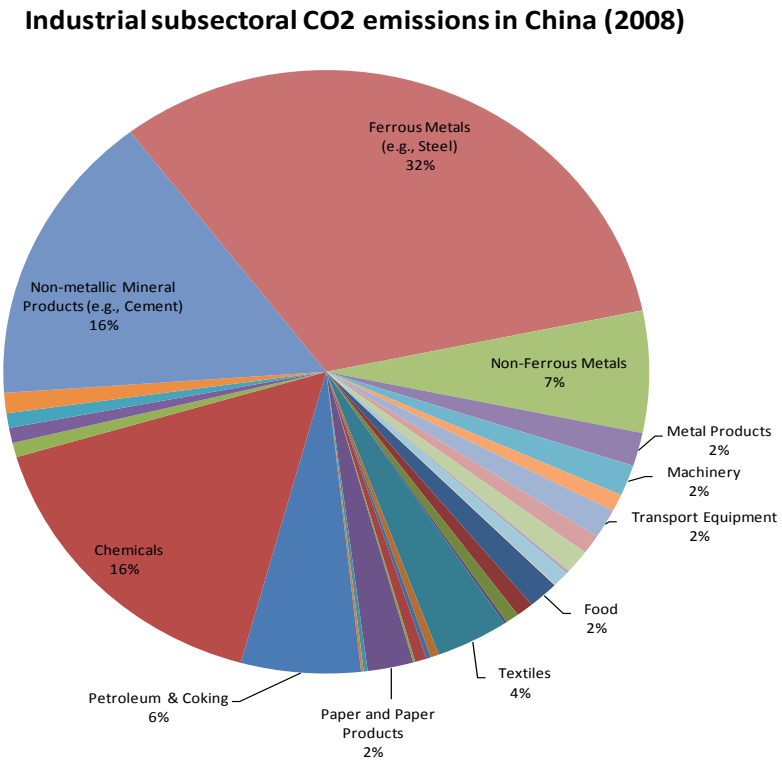

Figure 3. Manufacturing CO_2 Emissions in China (2008) (including emissions from T&D losses)

Table 5 shows CO2 emissions, final energy use, primary energy use, and industrial value-added for each of the manufacturing subsectors. Carbon emissions per final energy consumed as well as primary energy consumed are calculated. China reported industrial value-added by manufacturing subsectors through 2007. The 2008 industrial value-added values are derived based on 2007 reported values and growth rates, in order to calculate economic carbon intensities.

The China average results show that the manufacturing of plastics, metal products, and communication equipment have the highest CO_2 emissions per unit of final energy consumed, at about 0.17 tonne of CO_2/GJ in 2008. However, overall, carbon coefficients (CO_2/final energy consumed) of the majority of the subsectors are in the range of 0.11-0.17 tonne CO_2/GJ, with petroleum processing being the lowest.

More variance is seen among manufacturing subsectors when using economic carbon intensity indicators. Ferrous metal manufacturing (e.g., steel-making) has the highest CO_2 emission per unit of industrial value-added, at about 16 tonne CO_2/10,000 RMB (2005 RMB), indicating China's steel making remains in the stage of producing low value-added but energy-intensive steel products. Non-ferrous metal manufacturing and chemicals production have higher intensities as well, at about 13 tonne CO_2/10,000 RMB (2005 RMB), and 9 tonne CO_2/10,000 RMB (2005), respectively.

Table 5. CO_2 Emissions by Manufacturing Subsector in China (2008)

Manufacturing	CO_2 Emissions from Final Energy Use (including CO_2 emissions from T&D losses)	Final Energy Use	Primary Energy Use	Industrial Value-Added (2008)	CO_2 / Final Energy Consumed	CO_2 / Primary Energy Consumed	CO_2 / Value-Added
	Mt CO_2	TJ	TJ	Million RMB (2005 RMB)	tonne CO_2/GJ	tonne CO_2/GJ	tonne CO_2/10,000 RMB (2005 yuan)
Processing of Food From Agricultural Products	65	517,582	768,647	483,791	0.13	0.085	1.3
Food manufacturing	37	322,652	437,996	196,356	0.12	0.085	1.9
Beverage	28	252,422	329,327	192,914	0.11	0.086	1.5
Tobacco	6	42,857	69,618	297,823	0.13	0.082	0.2
Textile	155	1,100,442	1,881,029	492,043	0.14	0.082	3.2
Textile Wearing Apparel, Footwear, and Caps	18	129,474	219,615	230,916	0.14	0.081	0.8
Leather, Fur, Feather and Its Products	10	66,141	119,494	150,784	0.15	0.080	0.6
Timbers, Wood, Bamboo, Rattan, Palm and Straw Products	25	175,215	296,768	113,435	0.14	0.083	2.2
Furniture	4	31,774	55,957	66,520	0.14	0.079	0.7
Paper and Paper Products	98	812,102	1,139,055	177,537	0.12	0.086	5.5
Printing, Reproduction of Recording Media	9	55,262	108,803	70,477	0.15	0.079	1.2
Articles for Culture, Education and Sport Activity	5	35,720	68,790	59,400	0.15	0.079	0.9
Petroleum, Coking, Processing of Nucleus Fuel	256	3,006,586	3,300,278	292,709	0.08	0.077	8.7
Chemical Raw Material and Chemical Products	690	6,403,537	8,317,162	731,689	0.11	0.083	9.4
Medicines	33	263,159	389,910	242,639	0.12	0.084	1.3
Chemical Fiber	35	244,339	427,486	74,962	0.14	0.081	4.6
Rubber	33	221,026	408,875	96,635	0.15	0.082	3.5
Plastic	46	279,035	581,102	220,388	0.17	0.080	2.1
Non-metallic Mineral Products	671	6,274,997	7,633,066	513,685	0.11	0.088	13.1
Ferrous Metals	1,370	12,651,628	15,210,965	883,135	0.11	0.090	15.5
Non-ferrous Metals	278	1,734,391	3,474,685	455,658	0.16	0.080	6.1
Metal Products	76	448,557	953,426	313,716	0.17	0.080	2.4
General Purpose Machinery	71	508,069	848,330	541,052	0.14	0.083	1.3
Special Purpose Machinery	39	311,835	485,975	334,938	0.13	0.081	1.2
Transport Equipment	67	502,770	829,821	728,077	0.13	0.081	0.9
Electrical Machinery and Equipment	44	279,437	558,200	647,873	0.16	0.079	0.7
Communication Equipment, Computers and Other Electronic Equipment	54	324,085	692,023	804,279	0.17	0.078	0.7
Measuring Instrument and Machinery for Cultural Activity and Office Work	7	43,410	89,390	118,798	0.16	0.079	0.6
Artwork, and other Manufacture	35	216,882	433,835	91,551	0.16	0.081	3.8
Recycling and Disposal of Waste	1	9,891	17,836	18,532	0.14	0.080	0.8

Subsectoral CO2 Emissions at the Provincial Level

Since the provincial energy consumption of industrial subsectors is reported in final energy consumption values, the CO_2 emissions per unit of final energy consumption, as presented Table 5, were used for calculating provincial subsectoral CO_2 emissions, when detailed fuel use data were not available. Provincial CO_2 emissions by industrial subsectors of all the selected provinces are presented in Table 6 and Figure 4.

Table 6. Subsectoral CO2 Emissions (without T&D Losses) in the Selected Provinces in 2008 (Mt CO2)

	Henan	Shaanxi	Chongqing	Xinjiang	Liaoning	Shanxi	Guangdong	Shandong	Hebei
Manufacturing Total	**342**	**111**	**129**	**123**	**461**	**435**	**489**	**559**	**389**
Processing of Food From Agricultural Products	9	1	1	3	5	1	8	21	8
Foods	9	1	1	1	2	1	5	11	3
Beverage	6	1	1	0	2	1	3	3	2
Tobacco	0	0	0	0	0	0	0	0	0
Textiles	9	2	2	2	2	0	32	34	5
Textile Wearing Apparel, Footwear, and Caps	0	0	0	0	2	0	11	4	0
Leather, Fur, Feather and Its Products	1	0	0	0	0	0	7	2	2
Timbers, Wood, Bamboo, Rattan, Palm and Straw Products	2	0	0	0	1	0	4	6	2
Furniture	0	0	0	0	1	0	4	1	1
Paper and Paper Products	14	2	2	1	3	0	25	31	6
Printing, Reproduction of Recording Media	0	0	0	0	0	0	6	1	0
Articles for Culture, Education and Sport Activity	0	0	0	0	0	0	8	1	0
Petroleum , Coking, Processing of Nucleus Fuel	51	25	1	72	177	219	28	44	15
Chemical Raw Material and Chemical Products	51	29	56	10	36	46	29	98	37
Medicines	4	1	2	0	3	1	4	8	4
Chemical Fiber	3	0	0	1	4	1	3	4	1
Rubber	3	0	0	0	2	0	5	9	2
Plastic	2	0	0	0	3	0	29	4	3
Non-metallic Mineral Products	50	15	28	10	33	17	86	73	34
Ferrous Metals	51	12	13	16	151	103	35	106	246
Non-ferrous Metals	53	16	7	2	8	35	15	46	2
Metal Products	3	0	1	0	4	1	26	6	4
General Purpose Machinery	6	1	3	0	11	3	8	15	5
Special Purpose Machinery	5	1	1	0	2	2	6	6	2
Transport Equipment	5	2	10	0	5	1	8	8	2
Electrical Machinery and Equipment	2	0	1	0	3	0	30	7	2
Communication Equipment , Computer and	1	1	0	1	1	1	53	5	1

	Henan	Shaanxi	Chongqing	Xinjiang	Liaoning	Shanxi	Guangdong	Shandong	Hebei
Other Electronic Equipment									
Measuring Instrument and Machinery for Cultural Activity and Office Work	0	0	0	0	0	0	5	1	0
Artwork, and other Manufacture	2	0	0	0	0	0	7	3	0
Recycling and Disposal of Waste	0	0	0	0	0	0	1	0	0

Sources: Statistical Yearbooks for selected provinces, 2008 and 2007; IPCC, 1997a; IPCC, 1997b; NBS, 2010; NDRC, 2009; SERC, 2009; SERC, 2010.

Notes:

1. 2007 data for Xinjiang; 2008 data for other provinces.
2. Detailed breakdown of energy use by fuel for each industrial subsector in Guangdong, Shandong and Hebei are not available. National averages of CO_2 emission intensities were applied to these three provinces.

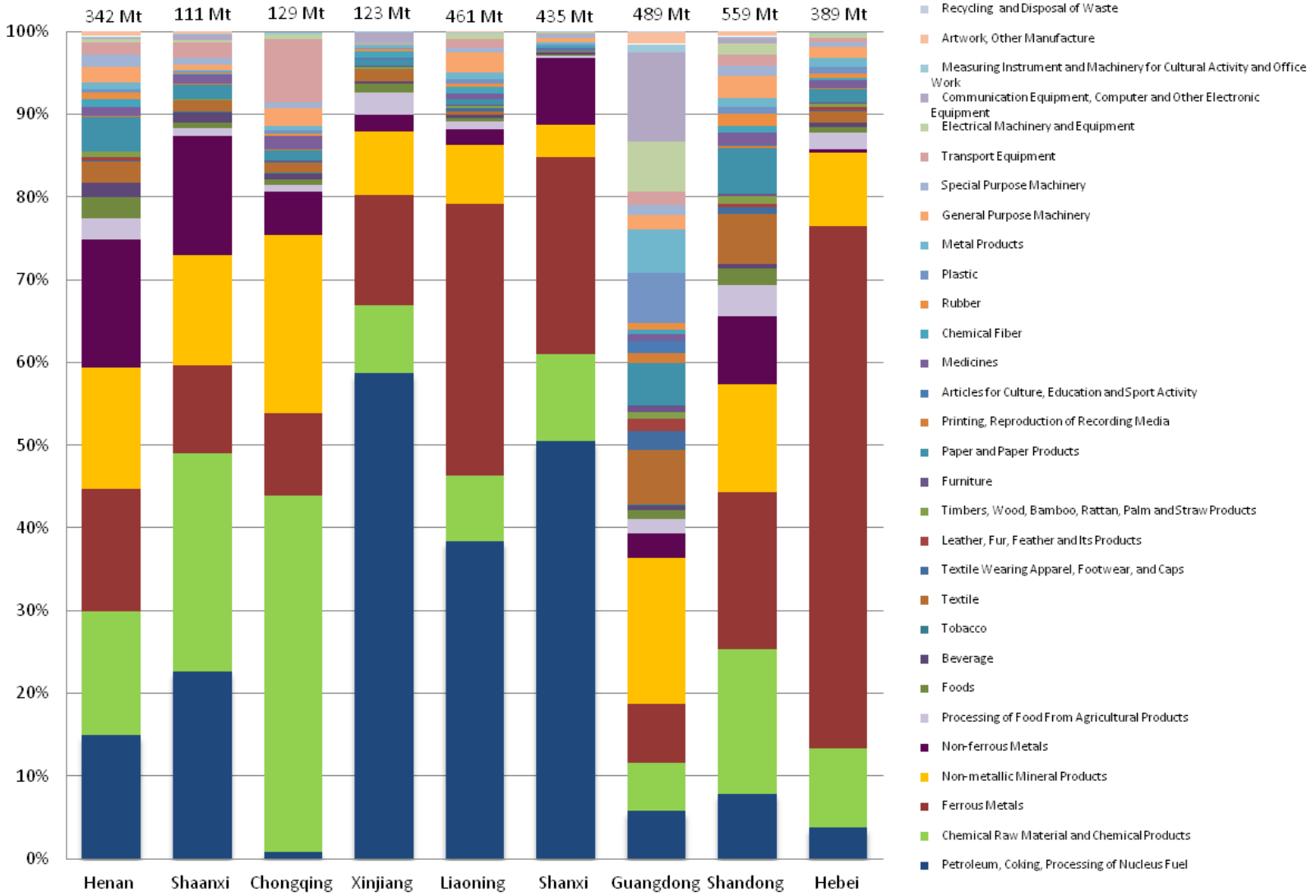

Figure 4. CO_2 Emissions of Industrial Subsectors in Selected Provinces (without T&D losses, 2008)

Provincial CO_2 emissions for Chongqing, Henan, Liaoning, Shaanxi, Shanxi, and Xinjiang were calculated based on energy use by fuel. CO_2 emissions for Hebei, Guangdong, and Shandong were calculated based on national average subsectoral CO_2 emissions per terajoule (TJ). Note that the results provided in this table do not account for emissions from T&D losses.

In Henan Province, the majority of CO_2 emissions are from five subsectors, including processing of petroleum, coking and nuclear fuel; chemicals production; smelting and pressing of ferrous metals; smelting and pressing of non-ferrous metals; and manufacture of non-metallic mineral products. Each of the five subsectors accounted for 15% of the total manufacturing CO_2 emissions in Henan in 2008 (see Figure 5).

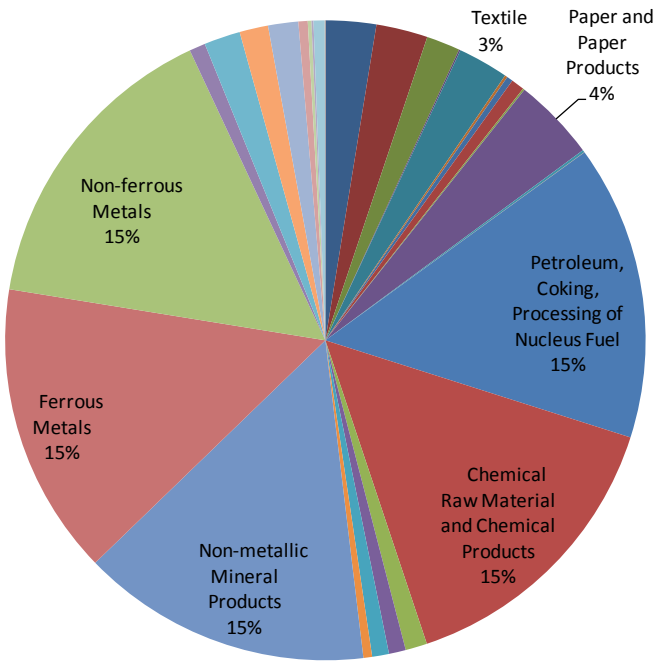

Figure 5. CO2 Emissions (without T&D Losses) of Manufacturing Sectors in Henan Province

In Shaanxi Province, manufacturing of raw chemical materials and chemical products is the largest CO_2 emitting subsector, representing 26%. The other four largest subsectors are processing of petroleum and coking (23%), smelting and pressing of non-ferrous metals (14%), manufacture of non-metallic mineral products (13%), and smelting and pressing of ferrous metals (11%).

The chemical sector dominated Chongqing's manufacturing CO_2 emissions, representing 43% of the total manufacturing emissions in Chongqing in 2008. Manufacturing of non-metallic mineral products, smelting and process of ferrous-metals and manufacturing of transport equipment also contributed significantly, with 22%, 10% and 8% of the total CO_2 emissions, respectively.

In Xinjiang Province, which has rich oil and natural gas resources, processing petroleum and coking is the largest and dominant subsector, accounting for 59% of the total manufacturing CO_2 emissions. The subsector of smelting and pressing of ferrous metals is the second largest CO_2 emitting subsector, or 13% of the total. Chemicals and non-metallic mineral products are the other two main industries.

Liaoning Province had the earliest discovered oil field in China and has a clustered steel industry; therefore, it is not surprising to see that CO_2 emissions from processing of petroleum and coking, as well as from smelting and pressing of ferrous metals are the highest, with shares of 38% and 33%, respectively.

CO_2 emissions of manufacturing sectors in Shanxi are also similarly concentrated in a few sectors, including processing of petroleum, coking and nuclear fuels (50%), smelting and pressing of ferrous metals (24%), manufacturing of raw chemical materials and products (11%), and smelting and pressing of non-ferrous metals (8%).

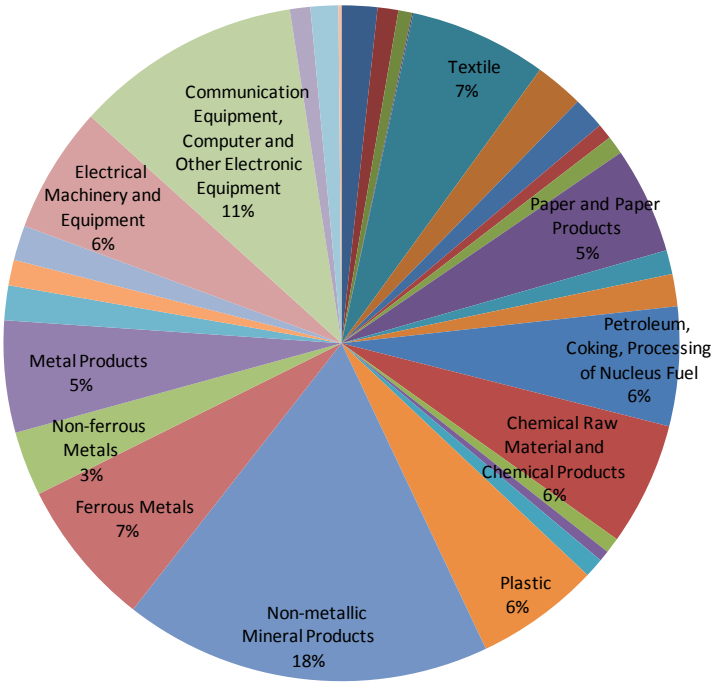

Figure 6. CO_2 Emissions (without T&D Losses) of Manufacturing Sectors in Guangdong Province (2008)

The structure of subsectoral CO_2 emissions in Guangdong Province differs greatly from other resource-rich provinces, as illustrated in Figure 6. Although manufacturing of non-metallic mineral products, ferrous and non-ferrous metals and metal products together still contributed 32% of total manufacturing CO_2 emissions in 2008, a larger portion of CO_2 emissions were from other light industries or higher value-added industries, such as manufacturing of communication equipment, computer, and electronic equipment (11%), textiles (7%), manufacturing of electrical machinery (6%), plastic (6%), and paper (5%).

Because Shandong Province has many large industries, such as steel and cement, its CO_2 emissions in the manufacturing sector are mostly from a variety of subsectors: smelting of ferrous metals (19%), manufacturing of raw chemical materials and products (18%), manufacturing of non-metallic mineral products (13%), smelting of non-ferrous metals (8%), processing of petroleum and coking (8%), textile industry (6%) and paper (6%).

For Hebei Province, the largest CO_2 emitting subsector is smelting and pressing of ferrous metals, accounting for 63% of the total. Manufacturing of chemicals and non-metallic mineral products represented 10% and 9% of the total manufacturing CO_2 emissions in Hebei in 2008.

Discussion

One of the main barriers for calculation of provincial level CO_2 emissions is data availability. Not all provinces provide energy data at the manufacturing subsectoral level, and even fewer provinces provide energy use by fuel. This poses a challenge in estimating provincial CO_2 emissions. For example, Jiangsu Province, which is much more active in the area of industrial energy efficiency than other western provinces, does not publish subsectoral energy data in its latest statistical yearbook. Guangdong Province does have energy consumption data for each subsector; however, only coal and electricity consumption are provided in addition to aggregated energy use in standard coal equivalent unit.

Limited data availability poses difficulties for calculation of physical and economic carbon intensities at the subsectoral level. NBS reports production data for key industrial products every year; however, reported energy data are not well in-line with production data. Energy consumption data are only reported at the two-digit manufacturing subsectoral level, without breaking down to the product level. Although some industrial associations report energy use and production for certain industrial products (e.g., cement production and energy use is reported annually by the China Cement Association), data reported in a collective and systematic manner for industrial products are needed for calculating physical carbon intensities. In the U.S., the Energy Information Administration (EIA) conducts the Manufacturing Energy Consumption Survey (MECS) every four years, with the most recent 2010 MECS survey conducted in 2011. The 2006 MECS surveyed industrial establishments, and allowed EIA to estimate their energy use for 21 three-digit industrial subsectors, 50 industry groups and industries. Economic carbon intensities by manufacturing subsectors are derived in this paper based on reported 2007 industrial value-added and growth rates. China stopped reporting industrial value-added by subsector in 2008 in the China Statistical Yearbook which poses further challenges for development of economic indicators in the future. Physical and economic carbon intensities are often used for benchmarking, for comparison to historical performance, or to the performance of other sectors and other countries, in order to identify the largest areas of mitigation potentials. Without sufficient data, such benchmarking potential analyses are difficult to undertake.

The use of transparent conversion factors is important for making CO_2 calculations. This study is based on conversion factors used by NBS (for the low heating values) and the *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories* (for the carbon coefficients). The electricity conversion from final to primary is based on the 2008 conversion efficiency of coal-fired power plants. National average T&D losses of 2008 are used for all provinces in the study. Electricity carbon emission factors for different provinces are from the NDRC's grid emission factors, which are calculated based on the *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. To further improve this study, provincial conversion factors (such as T&D losses and heating values) could be used, if available.

Conclusion

National policies have been established in China to reduce economic energy and carbon intensities, and at the provincial level local activities have been actively conducted, including publishing more detailed energy data for manufacturing subsectors in provincial yearbooks and developing greenhouse gas emission inventories based on IPCC methodologies.

This paper aims at providing transparent estimates of CO_2emissions at the manufacturing subsectoral level based on publicly available information in China, to identify key subsectors with the largest carbon emissions, and to understand the carbon emissions distribution across subsectors in different provinces, in light of China's efforts to develop low carbon economies.

The ferrous metals, petroleum, chemicals, and non-metallic mineral products subsectors are the largest contributors of manufacturing CO_2 emissions at the national level. Subsectors of ferrous metal and non-metallic mineral manufacturing have the highest CO_2 emissions per unit of industrial value-added, indicating these two subsectors produces low value-added but energy-intensive products. Emissions from manufacturing of textiles, and paper and paper products are high in China as well.

Each of the studied provinces has a slightly different industrial subsector structure in terms of CO_2 emissions, but most of the selected provinces' manufacturing CO_2 emissions are concentrated in a few energy-intensive subsectors, i.e., ferrous metals, chemicals, petroleum and coking, non-metallic mineral products. Guangdong Province, which differs greatly from others, has a more diversified structure of CO_2 emissions that are from light industries or higher value-added industries.

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